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Exploring the Use of Debate to Enhance Elementary Teacher Candidates' Argumentation Skills

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Abstract

The purpose of this action research is to introduce a debate activity contextualized in a scientific topic and explore its effectiveness in prompting teacher candidates' (TC) argumentation skills and affective perception of argumentation. We also investigate the separate impacts of the different aspects of the debate activity. Through comparing the quality of structural argumentation from 28 elementary TCs before and after the activity, we find that the debate has enhanced the TCs' argumentation skills in terms of the use of rebuttals. The transcript data further reveals that the confrontational aspect of the debate, i.e. Clash and Extension, are most effective in arousing high-level arguments as well as most risky in triggering negative TC attitudes towards argumentation. Through reflecting on our action of implementing the debate, we suggest a revised rubric for argumentation assessment in which sophisticated argumentation skills are epitomized by not only rebutting but also synthesizing various information and multiple perspectives to reach a conclusion.

Introduction

Scientific argumentation is an activity of individuals generating claims from evidence and communicating proposals to identity the optimum conclusion from its alternatives (Osborne et al., 2004). It has been addressed as one key learning objective in K–6 science standards (National Research Council [NRC], 2013). Argumentation is also important to other subjects because it could help generate an active learning community by entailing direct communication among students. To implement argumentation, elementary teachers need to develop considerable argumentation skills and informed understanding of instructional strategies for argumentation (Jimenez-Aleixandre & Erduran, 2007). Unfortunately, both in-service and pre-service elementary science teachers have been found lacking sophisticated knowledge of argumentation (Wang & Buck, 2016; McNeill et al., 2016). Researchers have identified barriers for preservice teachers to develop argumentation, including the deficiency of instructional strategies targeting argumentation (Wang & Buck, 2016; Cavagnetto, 2010; Crippen, 2012) and decontextualized instruction of argumentation (McNeill & Knight, 2013; Sampson & Blanchard, 2012). One possible approach to addressing those challenges is to have teachers experience the instructional activities designed for argumentation from a student's perspective.

Debate is one of the effective instructional strategies to teach argumentation since it involves rebuttals between people with different, normally opposite, opinions over a topic in question (Jimenez-Aleixandre & Erduran, 2007; Johnson & Johnson, 2009). Rebuttal, on the other hand, is the component that epitomizes sophisticated argumentation skills (Osborne & Patterson, 2011). On the other hand, it may result in destructive outcomes, such as passively aggressive competition, negative interpersonal relationships, and destructing misbehaviors of students (Chiu & Khoo, 2003). Thus, more studies on debate are needed to better understand how this pedagogy can be used in teacher education. In this study, we designed a debate activity contextualized in the scientific topic of the nature of light and implemented it in a science methods course for elementary Teacher Candidates (TC). The purpose of this course is to access TCs to different skills of scientific inquiry and strategies of inquiry teaching. Argumentation is one of the inquiry skills. With the debate activity, we tempt to promote TCs' argumentation skills and model the process of scaffolding argumentation in class. We break apart the debate activity and provide a practitioner account of the effectiveness of each aspect of the debate. We try to answer the following two research questions:

1. How does the debate affect the TCs' skills of using structural components of argumentation?
2. What are the impacts of each aspect of the debate on the TCs' skills of using structural components of argumentation and affective perception of argumentation?

Theoretical Framework

Two theoretical frameworks guide our work: scientific argumentation and debate. In this section, we first introduce Toulmin's model of argumentation, structural and dialogical argumentation, and the assessment of argumentation skills. Then we introduce debate as a specific dialogical argumentation, different aspects of a debate, and the use of debate in education.

Scientific Argumentation

Scientific argumentation is an essential element of many disciplines, such as science, as it is a legitimate way to deal with controversies (Kelly, 2007). The process of knowledge construction to some extent is equivalent to argumentation in terms of drawing conclusions based on evidence and identifying the optimum one from its alternatives. Argumentation has both structural and dialogical meanings (Jiménez-Aleixandre & Erduran, 2007). Structural argumentation refers to the rhetorical structure of an argument generated by an individual based on evidence and justification. Toulmin (1958) suggests a model of argumentation known as Toulmin's Argumentation Pattern (TAP) that defines key components of an argument, including claim, evidence (data), justification (warrant and backing), qualifier, and rebuttal (Toulmin, 1958). Rebuttal has been given priority as the most complex cognitive task (Kuhn, 2010; Osborne et al., 2004) and the salient feature that separates argumentation from other reasoned discourse, such as explanation (Osborne & Patterson, 2011). Dialogical argumentation refers to a social interaction where individuals with different opinions interact with each other sharing, evaluating, and negotiating arguments in order to identity the optimum one from alternatives (Jiménez-Aleixandre & Erduran, 2007).

In this study, we focus on the aspect of structural argumentation. Specifically, we measure individuals' skills of using the TAP components in their structural arguments. Correspondingly, we use the rubric designed by Osborne and colleagues (2004), which assigns hierarchical levels to different components of TAP (Toulmin, 1958). Level 1 to Level 3 are marked by the presence of Claim, Evidence (Data), and Justification (Warrant and Backing) respectively. Upper level arguments (Levels 4 – 5) are marked by rebuttals. The hierarchy represents a sequence from the least to the most sophisticated skills in structural argumentation. In this rubric, Level 5 arguments are defined as arguments with more than one rebuttal. We make a slight change to meet our research objectives by emphasizing the quality rather than the quantity of rebuttals. In our study, Level 5 arguments display one or more identifiable rebuttals that are well justified (Table 1).

Table 1. *Adjusted Rubric for Argumentation Assessment (Osborne et al., 2004)*

Level 1:	Level 1 arguments consist of a simple claim versus a counterclaim or a claim versus claim without any support.
Level 2:	Level 2 arguments consist of claims with supporting data, but no warrants or backings to connect data to claims.
Level 3:	Level 3 arguments consist of claims with supporting data and warrants or backings, but no rebuttals.
Level 4:	Level 4 arguments consist of claims with a clearly identifiable but weak rebuttal that is not supported by data, warrants or backings.
Level 5:	Level 5 arguments consist of claims and rebuttals that are well justified.

Debate

In this study, we design a debate activity as the intervention to leverage TCs' argumentation skills. Debate is one specific type of dialogical argumentation. A debate is a process of individuals proposing, communicating, disputing, defending and finally advancing opinions (Branham, 2013). Debating involves more intellectual confrontations than other argumentative interactions, normally direct and intense, between conflicting opinions. Conflicting opinions are compared, criticized, and tested against each other in the process of decision making (Branham, 2013). Participating in a debate requires participants to possess a unique viewpoint towards a topic, understand different perspectives, sort evidence and counter-evidence, and present arguments in a persuasive manner (Kennedy, 2009). A debate is composed of four aspects (Table 2). The salient features of a debate are clash and extension that involve much rebutting. The nature of a debate assures that it is a potentially advantageous strategy to address rebuttals in structural argumentation.

Table 2. *Four Aspects of a Debate (Branham, 2013)*

	Description
Development	Arguments are advanced and supported The positions of the contending sides must be clearly articulated, adequately explained and supported by reasoning and evidence.
Clash	Arguments are properly disputed Opposite opinions should confront each other, not simply a matter of disagreement but a product of demonstrated conflict between two competing argumentative positions.
Extension	Arguments are defended against refutation Opposing sides not only state their competing positions, but also extend the clash through multiple speeches
Perspective	Individual arguments are related to the larger question at hand A genuine debate should center on one specific proposition. Clash can be extended, but arguments are only important in relation to that proposition.

The history of science across all disciplines is full of debates, such as the debate about the nature of light in physics and that about evolutionary theory in biology. In science education, debate builds up a good platform to bring forth students' arguments. During a debate, students try to convince opponents of the truth or falsity of a certain viewpoint. Meanwhile, all sides with different opinions have equal opportunities to be heard and to reply directly to each other (Branham, 2013). Thus, students can actively engage in argumentation by accessing peers' opinions, evaluating alternate ideas about evidence, and thinking from multiple perspectives (Kennedy, 2009). Debating is also a pedagogical strategy effective in enhancing students' learning to deep conceptual understanding and boosting students' thinking from a lower level of what to think to a higher level of how to think (Zare & Othman, 2013). Debating also arouses intellectual conflicts that can potentially spark learners' inert ideas, motivate learners' perspective thinking, and produce learners' high-level cognitive reasoning (Johnson & Johnson, 2009).

Despite the advantages, researchers also pointed out that debate may result in destructive outcomes, such as passively aggressive competition, negative interpersonal relationships, and destructing misbehaviors of students (Chiu & Khoo, 2003). Furthermore, debates may disadvantage less represented learners (Parker, 2006). Due to those potential risks, debate has been rarely incorporated in science instruction in the real settings (Johnson & Johnson, 2009). There is limited research on the application of debate in teacher-preparation programs. The potential risks of debate cannot overshadow its benefits, but suggest that we should use it with caution. In this study, we follow the guideline (Table 2) to design our debate activity and investigate each aspect of it in promoting TCs' argumentation skills.

Literature Review

Argumentation is an advantageous instructional approach to engaging students in active learning (Simon et al., 2006). Despite its importance, argumentation rarely happens in traditional classes where teachers dominate class discourses (Ozdem et al., 2013). One of the barriers to argumentation implementation is teachers' insufficient skills and knowledge of argumentation as well as the corresponding pedagogical strategies (Sampson & Blanchard, 2012). Argumentation, as an intellectual activity, requires explicit instruction in teacher education (McNeill et al., 2016; Sadler & Donnelly, 2006). McNeill & Knight (2013) designed a workshop for K–12 teachers on argumentation. The workshop was composed of several key faucets, including the structural components of argumentation, argumentation assessment, challenges and successes from participating teachers' classrooms, and teaching strategies that support students' argumentation. The training was mainly through direct instruction of the theories. The results showed that the workshop successfully promoted the participating teachers' understanding of argumentation practices and their students' conceptions of argumentation. However, there were still challenges identified by the teachers, including the difficulty in analyzing and assessing the structural feature of student argumentation, and designing argumentation learning tasks for students, especially to develop "appropriate questions that provided students appropriate opportunities to engage in argumentation" (p. 966).

The challenges imply that theoretical instruction of argumentation alone may not be effective enough to support teachers to apply argumentation in their classroom. Understanding argumentation does not guarantee sophisticated argumentation skills of teachers. Teachers need to develop their argumentation skills the same way as students are expected to, e.g. experiencing legitimate argumentation activities (McDonald, 2010). On the other hand, successful examples of classroom argumentation can convince teachers of its effectiveness and feasibility and expand teachers' repertoire of argumentation-related pedagogies. In teacher preparation programs, TCs normally have limited access to argumentation in the field. Thus, it is especially important for TCs to experience legitimate argumentation activities from students' perspective. McNeill and Knight (2013) suggest that future efforts be carried out regarding the development of effective teacher education experiences on argumentation. Following that idea, Ozdem et al. (2013) had elementary TCs perform inquiry-oriented labs, which were in the format of exploratory experiments followed by critical discussions. Through analyzing the quality of arguments, the authors found that the labs were effective in developing the TCs' skill of applying a variety of data sources to support their arguments, not limited to reliable content knowledge. From TCs' personal experiences with applying a variety of analytical and structural schemes in argumentation, they developed understandings about the structural model of argumentation in terms of claim, evidence, and justification, and that inquiry labs are potential pedagogical practices for argumentation. The authors claimed that the TCs felt encouraged to incorporate argumentation in their future science classes after participating in that project.

The success of Ozdem and colleagues' project indicates that 1) experiencing argumentation practices is an effective approach to developing TCs' knowledge of argumentation; 2) modeling argumentation activities to TCs is a potential answer to the challenge of lacking appropriate contexts, such as a topic or a question, to embed argumentation. However, that project targeted primarily the components of claim, data, and justification (Toulmin, 1958), but overlooked the training of the most sophisticated component of rebuttal (Osborne & Patterson, 2011). It was probably because the authors did not explicitly scaffold rebuttals but treat argumentation as a lump in the critical discussion after the labs. We believe that debate is a potential approach to achieve this goal. Yet, there are few studies exploring the use of debate in developing TCs' knowledge or skills of argumentation. In addition, the strategy of debate has received both critics and credits, which requires further investigation (Chiu & Khoo, 2003; Johnson & Johnson, 2009; Kennedy, 2009; Parker, 2006; Zare & Othman, 2013). In this study, we follow the theory (Table 2) to design a debate activity after exploratory labs over a scientific topic. We decompose the debate and investigate how each aspect of the debate activity would affect TCs' skills of using TAP components (Table 1), especially rebuttal.

Methods

Approach

We utilize the method of action research to inform our practice. Action research is a systematic study that combines action and reflection with the intention of improving practices and/or understanding of an issue (Joy, 2007). Action research deals with both problem-posing and problem-solving of a practical issue identified as "problematic yet capable of being changed" (Joy, 2007, p. 298). Through reflecting on actions, practitioners meditate on and theorize their own work. Although action research usually starts in a small scale, it generates tested and critically examined evidence for the efficacy of a practice, which can be expanded in a larger context. Therefore, action research is a powerful tool to investigate closely the effects of an educational intervention on a learning community. The action taken in this study is a debate contextualized in the scientific topic of the nature of light. With the action, we tempt to promote TCs' skills of manipulating TAP components (Table 1), especially rebuttal in their argumentation. The overall efforts are guided by monitoring TCs' structural argumentation before and after the debate.

Context

This study took place in an elementary science methods course that lasted for 16 weeks offered by a university located in a northern college town. The class met twice per week and two hours each time. The major course objective was to foster TCs' conceptual, practical, and pedagogical knowledge of scientific inquiry. The course was composed of a series of inquiry-based activities modeled for TCs, which could be clustered into three sections: 1) The first three weeks were theoretical instruction of scientific inquiry, such as the instruction of the nature of science and the inquiry spectrum; 2) The next seven weeks were instructor introducing and modeling different inquiry skills, such as observation and manipulating variables; 3) The final six weeks were composed of comprehensive inquiry projects designed by the instructor. The debate activity happened in Weeks 12 and 13 as the second comprehensive inquiry project. It is important to emphasize that the comprehensive inquiry projects were aimed at immersing TCs in authentic inquiry experiences. Thus, the difficulty level of the content was above that of elementary science, i.e. for the level of TCs as college students. The instructor clarified to the TCs that the comprehensive inquiry projects, including the debate, could not be directly used with elementary students but should be simplified down to their level. The participants were 28 elementary TCs, three males and 25 females. The ethnical composition was 23 Whites, three Hispanics, and two Blacks. The course instructor, also one of the authors, was a doctoral student major in science education at the time of the study. He has a master's degree in physics. Pseudonyms were used in dialogues for the sake of privacy protection.

Action

A debate contextualized in a scientific topic is the main action in this study. Prior to the debate, explicit instruction of argumentation happened in the third week when the instructor introduced argumentation, including its importance in science, the components of argumentation (Toulmin, 1958), sample arguments, and argumentation activities in science teaching. The debate was about one of the historically famous disputes, i.e. the debate on the nature of light. Over centuries, physicists had argued about whether light is waves or particles. The wave and particle theory supporters had dominated the physics community alternatively as more optical phenomena were discovered. That debate ended up with the theory of wave-particle duality, i.e. light exhibits the properties of both waves and particles, which resulted in the quantum revolution in the 20th century.

Our debate activity imitates the debate among physicists. The debate contained three phases, which are pre-debate data collection, class debate, and post-debate reflection. Pre-debate data collection took two class periods in Week 12. In the first-class period, the TCs investigated optical phenomena through simple labs scaffolded by the instructor, such as light refraction and light interference. Then they summarized the behaviors of light. In the second-class period, the TCs explored the behaviors of traditional particles, like marbles and sand, and waves, like water waves. Then they summarized the characteristics of the two states of objects. Afterwards, the TCs chose a side regarding the nature of light in terms of being either waves or particles by fitting the properties of light into either of the two states. The class debate and post-debate reflection together took place in the third-class period in Week 13. Based on different aspects of a debate (Table 2), we broke up the second phase, i.e. class debate, into three stages: 1) Development – Each side giving opening statement by articulating their standpoint and presenting evidence as well as justification; 2) Clash & Extension – Free debate where the TCs from different sides engaging in clash and extension; 3) Perspective – Each TC constructing a model of light independently to answer the overarching question of what light is. During the post-debate reflection, the instructor revealed to the TCs how physicists in the history argued about the nature of light and came up with the theory of wave-particle duality. The nature of science was also discussed. The timeline of the course and the debate activity is shown in Table 3.

Table 3. *Timeline of the Course*

<table>
<tr><th>Timeline</th><th colspan="4">Content</th></tr>
<tr><td>Weeks 1 – 3</td><td colspan="4">Introduction to scientific inquiry</td></tr>
<tr><td>Weeks 4 – 10</td><td colspan="4">Introduction and practices of inquiry skills</td></tr>
<tr><td rowspan="7">Weeks 11 – 16</td><td rowspan="7">Comprehensive inquiry projects</td><td colspan="3">1) Exotic species</td></tr>
<tr><td rowspan="5">2) The nature of light debate</td><td colspan="2">Pre-debate data collection</td></tr>
<tr><td rowspan="3">Class debate</td><td>Proposals</td></tr>
<tr><td>Clash and extension</td></tr>
<tr><td>Model construction</td></tr>
<tr><td colspan="2">Post-debate reflection</td></tr>
<tr><td colspan="3">3) Physical versus chemical changes</td></tr>
</table>

It is necessary to point out that the debate activity, especially the labs, was conceptually oriented. No calculation was involved. We kept in account that the TCs were non-science majors who had limited physics content knowledge. Thus, the instructor emphasized to the TCs that the goal of the activity was not to master content knowledge but understand the process of scientific inquiry. The TCs were expected to develop qualitative understanding of the optical phenomena. For instance, in the reflection and refraction experiment, the TCs were expected to understand that when light travels from one medium to another, part of it goes through the boundary and the rest gets reflected. They did not need to measure any angles or distances. In addition, we did not use any sophisticated equipment for optical labs as that used in physics courses. All the lab materials were easily accessible in any elementary science classes. For instance, we used handmade double slits by cutting two slits on a piece of cardboard. By doing this, we wanted to convey to the TCs that "rocket science" is accessible and feasible to everybody.

Data Collection and Analysis

The major data source was the class videos of the three comprehensive inquiry projects (Table 3), from which we did not focus on dialogical argumentation in terms of the way TCs interacted or dialogued but structural argumentation in terms of the quality of arguments from individual TCs during class. All the three inquiry projects were guided by an overarching controversial question. The exotic species activity was before the debate, which was about whether a certain exotic species should be brought into the local ecosystem. The nature-of-light debate was about whether light is waves or particles. The physical/chemical change activity was after the debate, which was about whether a certain change, such as chewing a hamburger, is chemical or physical. In other words, the topics have no difference in stimulating argumentation among TCs. Only in the nature-of-light activity was debate explicitly structured by the instructor. The other two projects served as the references of the TCs' argumentation. We videotaped all three projects and later transcribed the videos to analyze the TCs' structural arguments.

Q1. Effectiveness of the debate activity. To answer the first research question, we compared the frequencies of TCs using each TAP component, especially rebuttal, during the debate activity and the two reference inquiry projects. We first identified arguments from the video transcripts and assigned a level to each argument according to the rubric (Table 1). Then we calculated the percentage of each level of argument in each inquiry project as Osborne et al. (2004) demonstrated. Afterwards, we plotted in a bar graph the percentage of each level of arguments in the three comprehensive inquiry projects. Through comparing the percentages of different levels, especially Levels 4 and 5 arguments, during the nature-of-light debate with that in the other two inquiry projects, i.e. exotic species and physical/chemical changes, we would know the TCs' use of TAP components before and after the debate activity, and then be able to summarize the impact of our action.

Q2. Influence of each aspect of the debate activity. The transcript of the debate activity was also used to answer the second research question. We first segregated the transcript into the stages of the debate activity (Table 3). Within each stage, we analyze the TCs' use of the TAP components (Table 1) and their affective perception of argumentation, from both verbal and non-verbal data, such as the TCs' tone and facial expressions. We coded both the positive (+A) and negative (-A) impact of each aspect of the debate activity. The codes are: 1) Positive impact in terms of fostering positive perception of argumentation, such as being engaged or interested (+A, i); 2) Positive impact in terms of prompting high-level argumentation with the presence of Level 4, 5 arguments (+A, q); and 3) Negative impact in terms of causing negative perception of argumentation, such as being resistant and uncomfortable (-A, i); 4) Negative impact in terms of leading low-level argumentation with the presence of Level 1, 2, 3 arguments (-A, q). With the coding, we could have a qualitative understanding about the impact of each aspect of our action, i.e. positive or negative and in what way.

Findings

Q1. How does the debate affect the TCs' skills of using structural components of argumentation?

The finding to the first question is that the debate has developed the TCs' skill of using rebuttal in their argument. Figure 1 shows that the percentage of arguments with rebuttals (Levels 4 and 5) in the exotic-species project was noticeably lower than that in the other two projects, which has a total of 10.45% (8.96% of Level 4 and 1.49% of Level 5). The nature-of-light debate has the highest percentage of upper level arguments with a total of 40.79% (19.74% of Level 4 and 21.05% of Level 5). The physical/chemical-change project is the second highest with a total of 36.00% (26.00% of Level 4 and 10.00% of Level 5). This result suggests that the TCs demonstrate most sophisticated argumentation skills (Level 4 and Level 5) in the debate activity, the physical/chemical-change project comes second, and the exotic-species comes last. It is reasonable considering that rebutting was encouraged, organized, and scaffolded in the debate activity. Interestingly, the percentage of Level 4 and 5 arguments stay relatively high in the physical/chemical-change project even when debate was not implemented. The TCs could spontaneously rebut with their peers without scaffolding from the instructor. The result indicates that the debate has helped the TCs develop the skill or at least the sense of using rebuttals in their argumentation or generally being critical. Most importantly, the impact continues after removing the intervention. In this sense, our action of debate is effective in promoting the TCs' use of high-level structural argumentation measured using rebuttals.

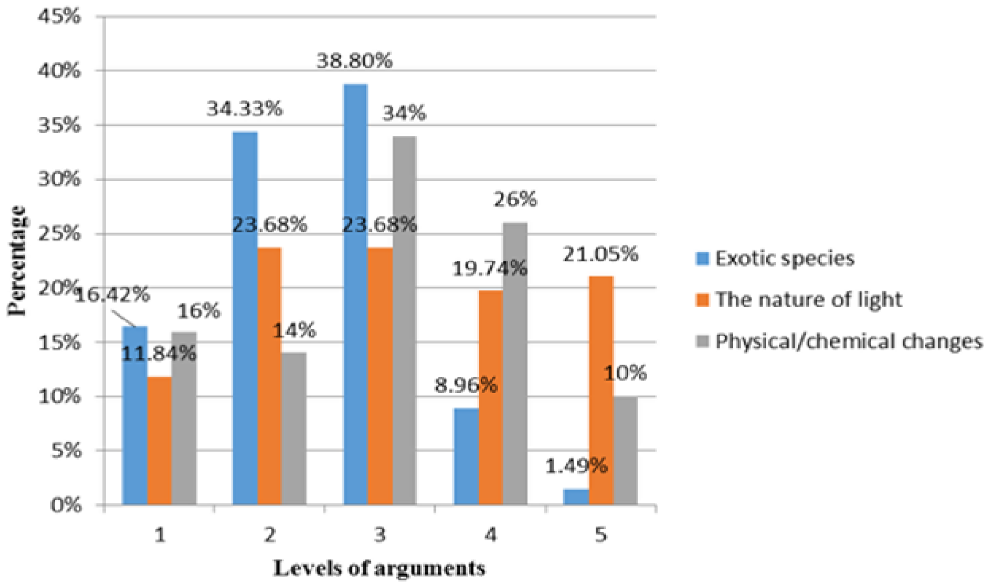

Figure 1. Percentages of Level 1-5 arguments in the three inquiry projects

Q2. What are the impacts of each aspect of the debate on the TCs' skills of using structural components of argumentation and affective perception of argumentation?

We decompose the debate activity to understand how it affects TCs' argumentation skills. The first finding to the second question is that pre-debate data collection affects the TCs' affective perception of argumentation positively mainly in a way of supplying empirical data for the class debate. This stage has limited impacts on the TCs' structural argumentation probably due to the involvement of the instructor. The second finding is that the stage of class debate had the most positive effects on the TCs' structural argumentation. Among the four aspects (Table 2), Clash and Extension are more effective than Development and Perspective in refining and promoting the quality of structural arguments, but also more likely to trigger negative emotions of TCs that prevents argumentation from proceeding. The third finding is that the post-debate reflection has positive effects on the TCs' affective perception of argumentation since it helps them realize the importance and necessity of argumentation, but not much on their structural argumentation.

Finding 1: Pre-debate data collection. Argumentation rarely happened during the pre-debate data collection. The TCs followed the instruction of each lab strictly. While encountering difficulties or disagreements, the TCs relied on the team leader or the instructor to solve the problems. Argumentation happened during the instructor-guided discussion about the behaviors of light and that of particles and waves. Quote 1 below is an example.

Instructor: As for the light filter, you see one color on the screen which is the color of the color filter. How do you explain that? What does that tell you about light?
Katie: Maybe it is blocking all other colors, except for that color of the color filter (Claim).
Instructor: So, are you saying that light is composed of different colors?
Katie: Yes, because like when we did the prism, it reflected the stripes of a rainbow

7 (Evidence), *the prism was clear, and you can see through it, and there wasn't any color*
8 *(Alternate). As for the color filter paper, it is blue. That color blocked out all the colors*
9 *light has, only representing the color of the filter paper, which is blue* (Justification).
10 (Level 3) (-A, q)

Katie's argumentation was not spontaneous but prompted by the instructor. Originally, Katie's argument simply contained a claim (Line 3). After the instructor's prompting, Katie elaborated on her statement by citing lab data (Line 6) and considering alternative explanations (Line 7). While she was citing the evidence that a prism could separate light into different colors, she denied the possibility that the prism itself released different colors. Katie justified her answer well. However, since there was no identifiable rebuttal, her argument stayed at Level 3. In other words, the instructor's prompting had a positive effect on Katie's structural argumentation, but not enough to raise it up to upper levels. It is also worth mention that Katie was a unique case. She took the role of a spokesperson who communicated with the instructor on behalf of the entire class. Other TCs were not as engaged as Katie was. Therefore, pre-debate data collection affected the TCs' affective perception of argumentation positively but had limited impacts on the TCs' structural argumentation.

Finding 2: Class debate. ***Development.*** Development was the process that the supporters of the wave and particle theories proposed an opening statement about the nature of light. Compared to the other three components (Table 2), development is most engaging to the TCs. The TCs felt comfortable generating arguments from their lab data and complementing the statements from peers on the same side. Quote 2 below is an example of the wave-theory supporters presenting their proposal:

1 *Rachel: Light is a wave* (Claim), *because it can go through small spaces. It breaks apart*
2 *with circles with like we saw one or two small circles and rings around it, so it's spread*
3 *out* (Evidence). *That's the same to the wave because when it goes through the slits, or a*
4 *small circle that we cut out, it went through it and spread out and covered like all the*
5 *space of the water (Justification). So, they display very similar characteristics.* (Level 3)
6 (-A, q)
7 *Lucy: Yes [excitedly],* (+A, i) *like, light spreads like wave spreads, and like particles, for*
8 *instance, like, they don't do that. They just bounce off an obstacle, or they are, just like,*
9 *they stop, particles cannot go around or spread out* (Level 4) (+A, q).

Rachel gave a Level 3 argument on why light is a wave. She presented the evidence from the pre-debate labs and articulated why that evidence supported the wave theory (Lines 2–5). Lucy voluntarily complemented Rachel's argument by presenting the counter-evidence against the participle theory (Lines 7–9). The rebuttal made her argument Level 4. The situation was similar with the particle supporters as shown in Quote 3 below.

1 *Linda: Light is a particle* (Claim), *because when it hits a solid, it is stopped by it*

2 (Evidence 1), *which is what a particle is. And it travels in space, and therefore doesn't*
3 *need medium to travel, um, it's like light travels in space but you don't see anything in*
4 *space* (Evidence 2). *Uh, Light bounces off objects, and that's how we see objects. So, it*
5 *bounces, it's a particle. And if light bounces, and it is stopped by an object, it has to be a*
6 *solid* (Justification). *I mean like waves would go around it, even if you put like (an*
7 *obstacle), it would find some ways to, there wouldn't be shadow anyway* (Rebuttal) (Level
8 4) (+A, q).

Linda provided two pieces of evidence to justify why light is particles (Lines 1–4). Meanwhile, she presented counter-evidence against the wave theory (Lines 6–7). Linda's argument suggests that she has developed the skill of deriving conclusions from data, which involves not only justifications but also rebuttals in terms of identifying counter-evidence to challenge the opposing proposal. Considering the high-level arguments provided by both sides and the fact that the TCs from the same side actively contributed to the construction of their proposal, it is reasonable to conclude that the component of development had a positive impact on the TCs' argumentation.

***Clash and Extension*.** Clash and Extension happened during free debating when the TCs talked directly to each other. There were cases in which the quality of argumentation decreased. For instance, after being challenged by Jack, Linda caved to avoid a conflict by saying that *"Right, so I guess it's [light] a wave too."* (-A, q) Generally, upper level arguments (Levels 4–5) appeared more frequently than that during development. Quote 4 below is an example.

1 *Tom: If you have like a candle, like you put your head in front of the candle, you can still*
2 *see this light of this side* (Evidence), *it's not like the candle is this big, light can still go*
3 *around it* (Justification). (Level 3)
4 *Jennifer: Because, again, the light from the candle is already bigger than the object*
5 *(Rebuttal).* (Level 4)
6 *Rachel: But the head is like this size [demonstrating with a palm] and the flame is like*
7 *this [demonstrating with a fist]* (Rebuttal) (Level 4)
8 *Jennifer: Light from the candle is already going in every direction, so it can bounce to the*
9 *other side* (Rebuttal) (Level 5) (+A, q)
10 *[Tom and Rachel looked at each other, laughed, then they put on a grudging face, and did*
11 *not respond to Jennifer anymore]* (-A, i)

Rachel and Tom were wave-theory supporters who debated with Jennifer who was a particle-theory supporter. Tom cited the evidence that light could travel around an obstacle (Lines 1–3). Jennifer challenged that piece of evidence by pointing out that the size of the light source was larger than the obstacle (Line 4). Rachel defended by demonstrating the sizes of the light source and the obstacle (Lines 6–7). Neither Jennifer nor Rachel articulated how the factor of size influenced that particular situation, so their arguments were both Level 4. Then Jennifer argued from another perspective that light could bounce off an object and reach the other side of the obstacle (Lines 8–9). Her explanation reasonably justified her rebuttal, which made her argument Level 5. However, Tom and Rachel seemed not to be convinced by Jennifer (Lines 10–11). They laughed probably because they thought that Jennifer's argument was unreasonable or Jennifer was arguing for the sake of argue, which was a little disrespectful. Eventually, they chose to keep their own opinion and stop debating with Jennifer. Afterwards, Jennifer extended her argument to another level, as shown in Quote 5 below.

1 *Jennifer: Let's say we are in this room. And somebody yells in that room (the next room),*
2 *we can hear it* (Evidence), *because sound is a wave, and wave travels through*
3 (Justification). *But if you have a light turned on in that room, you guys are in this room,*
4 *you won't be able to see it, because light can't go through. Light bounces off that because*
5 *it's [the wall] solid* (Rebuttal). (Level 5) (+A, q)
6 *Emma: What if the wall is clear?* (Rebuttal) *Like, when you shed light on the white, it can*
7 *still travel through, like you can still see the light on the other side of the white* (Level 5).
8 *Lucy: Yes, like the door of your room is closed, and the hall way light is on, the light*
9 *seeps through the bottom of the door and makes your room lighter. Like there is an*
10 *obstacle, but it goes around the obstacle* (Rebuttal). (Level 5) (+A, q)
11 *(There were a couple of rounds of debating between Jennifer and Lucy)*
12 *Jennifer: I mean gas is particles too, and gas could seep through the bottom of your room,*
13 *and like, kill you, whatever* (-A, i). *I mean you guys just think that sand is tangible solid*
14 *while some other particles are not, that can spread throughout your room.*
15 *Lucy: No. [pause] OK, whatever [unwillingly].* (-A, i)

Jennifer first argued that light is particles by comparing light with sound. She also cited real-life experiences to justify her claim (Lines 1–5), which made her argument strong. Then Emma challenged Jennifer's argument with another real-life experience (Lines 6–7), so did Lucy (Lines 8–10). Both Emma and Lucy elaborated on how their evidence disproved Jennifer's claim. Their rebuttals were well supported, which made their arguments Level 5. In this sense, the component of clash and extension helped the TCs to think deeper, more critically, and more comprehensively during argumentation. However, this component also had a negative impact on the TCs' perception of argumentation. Jennifer probably felt angry when she said gas could "kill you" (Line 13). Although she seemed to be still reasoning with her opponents (Line 13–14), her argument went overboard to personal attacks. Lucy disagreed with Jennifer by saying "No," but she decided to quit arguing (Line 15) probably because she did not have the mood or see the necessity to argue. The second part of argumentation between Jennifer and Lucy went intensely. The evidence suggests that the component of clash and extension had both positive and negative impacts on the TCs' argumentation.

Perspective. The debate activity fulfilled the requirement of perspective (Table 2) because the

TCs arguments were closely related to the overarching question regarding the nature of light. As a procedural component, perspective was the TCs working individually constructing the model of light after the debate. During this process, many TCs could thoroughly consider the evidence from both sides. Quote 6 below is the answer from Lucy.

Lucy: The nature of light in my opinion is consisted of waves a light. A wave is made up of thousands of particles that are travelling in the wave (Claim). *It can be blocked by an opaque obstacle but the waves will find a way to seep through or bounce/ reject by the object* (Justification). *For example, light can be blocked by a door but you will still see light trying to get through the sides of the door* (Evidence) (Level 3) (-A. q)

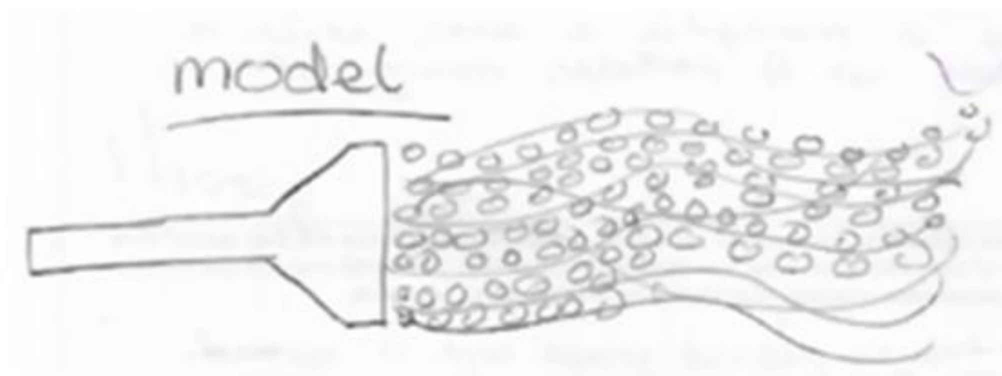

Figure 2. A model of light constructed by a TC

Lucy's answer suggests that although she disagreed with the particle theory, her debate with particle-theory supporters, like Jennifer, did sway Lucy to the particle side a little. Lucy probably realized that the wave theory alone could not explain all the light phenomena. Although Lucy still insisted that light is waves (Line 1), she assimilated some ideas from the particle theory (Line 2). She also justified well the combination of the two theories. Her argument reached Level 3, but not Level 4 or 5 due to the absence of rebuttals. Therefore, we could not conclude that the component of perspective had a positive effect on the TCs' reasoning. Another fact worth notice is that Lucy's model is close to Einstein's photon model of light (Figure 2). In other words, non-physics-major students to some extent could accomplish the knowledge construction of physicists after being fully exposed to the entire reasoning of their work. Through comparing the four aspects of debate, we found that Clash and Extension were more effective than Development and Perspective in refining and promoting the quality of structural arguments, but also more risky in causing negative feelings of the TCs that influenced their engagement in argumentation.

Finding 3: Post-debate reflection. The post-debate reflection was the instructor introducing the history of physicists debating over the nature of light and the TCs' reflection on the entire debate project. Quote 7 below is an example of the TCs' comments.

Tom: The physicists made explanations, like, their words, I guess, were not observation. They inferred from their observations, so they were not absolutely sure about their conclusions, because they might be wrong. Like us, we collected data, like the obstacle thing, light goes around the obstacle. We had different explanations for that, but who

5 *knows which one is right? I mean, you can't literally see light moving. So, I feel that*
6 *explaining data is really a subjective thing. (+A, i)*

Tom connected the stories of physicists to his exploration experiences, from which he analyzed the application of the nature of science to this vignette, such as scientific claims are inferences from observations (Line 1), scientists may be wrong (Line 3), and generating explanations is subjective (Line 6). Based on Tom's statement that "we collected data … we had different explanations for that," it is reasonable to assume that he obtained a sense of ownership over the debate activity. We coded it as a positive impact on Tom's affective perception. He also realized the role of argumentation in science, which suggests that the post-debate reflection did help the TCs understand the nature of argumentation even though it did not enhance their skills of structural argumentation.

Rethink of Upper-level Arguments

In this study, we used the rubric designed by Osborne and colleagues (2004) that valued rebuttal as the unique element of upper-level arguments (Levels 4–5). After reviewing our data, we found some Level 3 arguments with a high quality. Take Quote 1 for example, Katie did consider and rule out the possibility that the prism released lights of different colors by stating "*the prism was clear, and you can see through it, and there wasn't any color"* (Line 7). In Quote 6, Lucy did consider both the wave and particle theories while generating the model of light by stating that light is "*A wave is made up of thousands of particles that are travelling in the wave"* (Line 2). Both Katie and Lucy considered alternative explanations and came up the one reasonable to them. However, neither of the arguments were Level 4 or 5 because of the absence of rebuttal. Another example is the argumentation in a different context, as shown in Quote 8 below.

1 *Lisa: If it's chemical formula which changes, it's a chemical change* (Claim)
2 *Jennifer: [In a tone of disagreement] We at least could see the chemical changes*
3 (Evidence)*… So, I think you can say that there is something new that is produced [in a*
4 *chemical change]*
5 *Lisa: I think that still goes along with this* (Claim), *because even though this one,*
6 *we said water boiling would be a physical change cause water isn't change. Like this one*
7 *is bubbling* (Evidence)*, it's two chemicals going together and making a different*
8 *chemical…*(Justification) (Level 3)

Lisa made a claim that a chemical change was a change in chemical formulas (Line 1). Then Jennifer disagreed by stating that it was a change that produces something new (Line 3). Lisa realized that the challenge from Jennifer was not contradictory to her opinion. Instead of rebutting, Lisa pointed out the similarity between their ideas that a new product in a chemical change was the result of the change in chemical formulas (Lines 5–8). Lisa' argument did not reach Level 4 or 5 because of the absence of identifiable rebuttals. However, it was indeed an effective argument that reflected Lisa's capability of synthesizing a variety of information. The rubric that we used failed to give credits to arguments of this kind.

Discussions and Conclusions

In this study, we have thoroughly introduced the design of a debate activity and examined the impacts of its different aspects on TCs' structural argumentation skills and affective perception of argumentation. Overall, our action has a positive impact in TC training of argumentation. The comparison of TAP components shows that the debate activity has developed the TCs' skills of using rebuttal, which is a component overlooked in previous studies regarding argumentation in teacher education (McNeill & Knight, 2013; Ozdem et al., 2013). Debate is an effective pedagogical strategy for argumentation implementation since it externalizes intellectual contradictions through confronting individuals to each other's ideas directly (Kennedy, 2009). The process of conducting the debate activity illustrated in this study can be applied in other topics and disciplines. This contribution would be useful to the practitioners of teacher education who are interested in argumentation or class discourse.

The qualitative data of classroom videos about different aspects of the debate support the importance of pre-debate preparation serving as the evidentiary foundation for debate and post-debate reflection serving as the meta-cognition of argumentation (Ozdem et al., 2013). Our finding about Clash and Extension suggests that the feature of direct confrontation in debate is a double-edged sword. On the one hand, it did enhance the TCs' conceptual reasoning and the quality of their structural arguments. On the other hand, it also disadvantaged some TCs by damping their enthusiasm towards argumentation or diverting their attention from knowledge construction to winning a debate. Those individuals seemed to benefit more from a rebuttal-free environment, like the stage of perspective in the debate, or a collaborative environment, like the pre-debate data collection. Thus, practitioners of teacher education need to be cautious about the extent to which rebutting be emphasized while implementing debate.

The negative impact of rebuttal, along with the arguments in this study that had high qualities but low levels, may indicate that Osborne and colleagues' rubric (Table 1) is biased. Maybe rebuttal should not be the exclusive mark of upper-level arguments. Rebutting is the competition between two opposing sides in a sense that one must be chosen, and both cannot be true simultaneously (Branham, 2013). However, the answer to many scientific questions, such as the one regarding the nature of light, is much more complex than the yes–no dichotomy. While challenging or criticizing alternate opinions, arguers should also acknowledge the merit in their opponents and be willing to modify their own opinions. Furthermore, rebutting does not help with constructing a collaborative learning environment (Jiménez-Aleixandre & Erduran, 2007). Overemphasizing rebutting may indulge arguers in competition wherein their intention is not to understand something but to win. Such a situation may disadvantage academically vulnerable students (Johnson & Johnson, 2009). Both cooperation and confrontation are important in argumentation. The valuable characteristic of rebuttal is the reasoning process in terms of weighing alternative explanations considering evidence. The problem is that the idea of accepting one of the candidate accounts and discarding the rest is not the only way to draw a conclusion. We feel necessary to add another branch in upper-level argumentation and suggest a revised rubric for argumentation assessment (Figure 3).

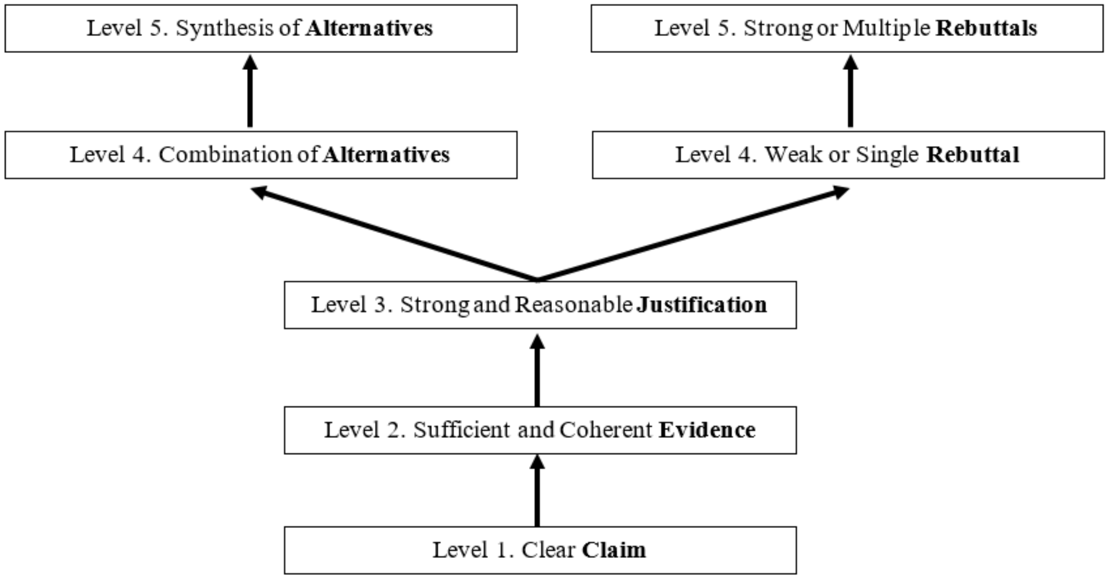

Figure 3. A revised rubric for argumentation assessment

The "Y" shape model has a new branch compared to the Osborne and colleagues' rubric (2004). The upper-level arguments are marked by a thorough consideration of a variety of viewpoints followed by a careful synthesis of them. Level 4 argumentation exhibits a clear consideration of different perspectives towards an issue. However, the conclusion is equivocal or simply cumulating different viewpoints. Level 5 argumentation is also characterized by a careful analysis of different viewpoints. The difference is that the conclusion is well synthesized and conforms to most of the evidence available. The new rubric does not deny the importance of rebuttal as the most complex and sophisticated skill associated with argumentation (Kuhn, 2010; Toulmin, 1958). The complexity of rebuttal does not exist in the aggressive discourses but the synthesis of a large body of information and the comprehensive consideration of various perspectives. We maintain that idea and suggest an alternative to rebuttal in solving contradictions, which is beneficial to constructing a collaborative context for argumentation in teacher education. Apparently, the validity and reliability of this rubric need to be verified by future empirical studies.

To sum up, debate is beneficial in externalizing individual's ideas for direct communication, but risky in triggering negative perceptions of arguers. Emphasizing collaboration and appeasing confrontations are a promising approach to diminishing the disadvantage of debate. Our success with the nature of light debate suggests that debate is a promising approach to teacher education on argumentation. The debate activity could of practical importance to TCs in designing student-centered teaching in various content areas. Research wise, the revised rubric can be used to assess the structure of arguments from the clarity of claim, the relevance and sufficiency of evidence, the reasonability of justification, and the capacity of thinking from multiple perspectives. However, the rubric is less capable in evaluating the substantial aspect of argumentation, such as logical consistence and the authenticity of grounds on which arguments are based. Simon et al. (2006) claimed two general perspectives that a rubric for argumentation assessment needs to be built upon: 1) the rhetoric structure in terms of the quality and coherence of its key components; 2) the scientific reasoning and thinking embedded in discourses. These are the theoretical guidelines for future work in revising the criteria for argumentation assessment.

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